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CONTRIBUTIONS TO THE PHYSIOLOGY OF WATER AND SODIUM CHLORIDE **/413

Otto Cohnheim, Kreglinger, and Kreglinger*

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Results of experiments on the water and sodium chloride metabolism in human subjects, under altitude and lowland conditions, at rest and under physical exertion, are discussed, with tabulated data on excretion and retention of chlorine. Increased muscular work at high altitudes (4600 m) led to a transient hydremia, without change in hemoglobin concentration. Profuse perspiration resulted in chlorine depletion, compensated later by increased chlorine retention. Reduction in the HCl content of the gastric juice was observed. Author

Ever since the investigations by Miescher (Bibl.1, 2, 3) and his followers, it has been an established fact that the number of red blood corpuscles per unit volume increases in both human and animal organisms with decreasing barometric pressure, meaning that the blood becomes more concentrated. At an altitude of 1800 m, Abderhalden (Bibl.4) observed this increased concentration in a large number of animal experiments, while he found no corresponding rise in the absolute hemoglobin content or at least not at a constant rate or to the same extent. Since then, the entire phenomenon has again become questionable, in view of the fact that Zuntz (Bibl.5) and his coworkers found no increase in erythrocytes per

* From the Monte Rosa Laboratory, A.Mosso Institute and Margherita Hut.

** Numbers in the margin indicate pagination in the original foreign text.

unit volume at high altitudes; in fact, they observed values that fluctuated sharply within extremely short periods of time, so that they came to the conclusion that the various values of the skin vessels and the differing distribution of the blood corpuscles in the skin capillaries were mainly responsible for /414 all observed differences. Similarly, Fuchs (Bibl.6) found an increase in the number of blood corpuscles in human subjects, at altitudes of 3000 and 4500 m, but this increase was by far not as pronounced or as regular as in rabbits.

Under these circumstances, we found it advisable to make new investigations on the behavior of hemoglobin and blood corpuscles. It could not be assumed per se that the difference in the results of the various authors was due merely to their methodics or to the conduction of the tests; rather, one could expect that the amount of red blood corpuscles per unit volume depended not only on the altitude, i.e., on the barometric pressure, but also on the differing reaction of the experimental subjects or experimental animals. Grawitz (Bibl.7) voiced the suspicion that the greater water loss at high altitudes might be the reason for the increase in blood corpuscles per unit volume; Weiss (Bibl.8) and Abderhalden actually found in their experimental animals a concentration of the blood but no increase in absolute hemoglobin content. Similarly, Fieschler (Bibl.9) found a hemoconcentration in rabbits, on reducing the atmospheric pressure in the pneumatic chamber. However, it is known that water loss or water intake generally do not lead either to hemoconcentration or hydremia; rather, blood has the capacity of maintaining its composition by giving off excess water to the water reserves of the tissues or by extracting water from these reserves (Bibl.10, 11, 12). This constituted a contradiction which could possibly be explained by assuming that the type of water loss played a certain role. The greatest water loss in human subjects takes place by sudation. However, perspiration will occur only if the sweat glands are stimulated by a specific stimulus (Bibl.13, 14, 15, 16). Without such a stimulus, the skin will give /415 off no water; in general, perspiration itself at high altitudes should not differ from that in the lowland. However, such a difference might occur in the water vapor dissipation through the lung. Such transpiration is not ruled by a specific activity of the body but exclusively by heating of the respiratory air to body temperature, on contact with the moist respiratory passages, and saturation of this air with water vapor. Usually, the air in high mountains is cool and dry and the water evaporation is increased because of the lower barometric pressure. Consequently, it could be expected that the amount of water lost by purely physical processes rather than because of muscular activity would be greater at high altitudes than in the lowland, meaning that the concentration of the blood as well as the increase in number of blood corpuscles per unit volume could be explained by this.

The water loss of the organism at high altitudes was calculated by Zuntz and coworkers; however, they either determined only the loss during sustained muscular work (mountain climbing) or the total loss per 24 hrs, while they made no comparison of the water loss at work and at rest, between lowland and high mountains. Therefore, we made plans to determine the water loss in the lowland and at high elevations, under differing conditions such as rest, muscular work, perspiration without muscular work, and to determine simultaneously the concentration of hemoglobin in the blood, under these same differing conditions.

The control experiments in the lowland were made in Heidelberg and in Coblence, while the high-altitude tests were conducted in the Monte-Rosa Laboratories. During the time from July 31 to August 15, 1909, we stayed at the Institute Mosso on the Colle d'Olen, i.e., at an altitude of about 3000 m; between

Aug.7 and 10, we stayed at the Margherita Hut (4560 m). At this point, we /416 wish to express our appreciation to the Director of the Laboratory, Dr.Aggazzotti, for his kind support and his willing cooperation, by making available all facilities of his excellently equipped Institute. In addition, we wish to thank the Central Committee of the German and Austrian Alpine Club who, on request, gave financial support to our investigations.

Animal experiments were not in question for the purpose of our studies. Of the conventional experimental animals, rabbits, guinea pigs, and rats are so small that they need no heat dissipation by water evaporation. Because of their relatively large body surface, they will produce adequate heat loss without such evaporation. The conditions are similar in dogs, where the physiological heat regulation plays a lesser role than in human subjects; if dogs evaporate water at all, they do it over their respiratory tract. The conditions of water metabolism are so intimately connected with the heat regulation that such animals cannot be compared with human organisms. Animal experiments on water metabolism could be done only on very large animals that are able to perspire, for example, on horses. However, for this we were not equipped.

Therefore, we made self-experiments exclusively. On the Margherita Hut and during a part of our stay on the Colle d'Olen, Dr. Fr.Kestner volunteered as test subject. Thus, the subjects included:

G.Kreglinger I, age 55, height 186 cm, weight 77 kg, slim, healthy;

G.Kreglinger II, age 27, height 182 cm, weight 87 kg, healthy;

O.Cohnheim, age 36, 170 cm, weight 84 kg, healthy;

F.Kestner, age 30, height 168 cm, weight 76 kg, healthy.

The ratio of height to weight already indicates that the constitutional /417 appearance of the four subjects differs widely. For example, Kreglinger I is tall, thin, and perspires little, while Cohnheim is stout and perspires readily. All four of us were mountain climbers for years and used to physical exercise, but came directly from the lowland at the beginning of the experiments and thus were quite untrained.

As the criterion for water loss we simply used the decrease in weight during a predetermined period of rest, usually during the night or during an ascent.

In Heidelberg, C. and Kr. II climbed the Heiligenberg, in which the first and last portion of the path, comprising the main portion of the incline, led through the forest, constantly rising. The altitude difference was 345 m; in the ascent, we wore regular mountain-climbing clothing. In Spring and in the untrained state, we required 38 min for the ascent and 23 - 25 min for the descent; in Fall, after return from the Alps, the corresponding values were 35 and 22 min. Between the individual weighings, about 90 min elapsed. In Coblence, Kr.I ascended the Kuhkopf (foothill in the Hunsrück) on July 4 and 25, on Sept.29, and Oct.17. The path followed the highway for 2 km and then led through the woods, at a gradual rise to a height of 375 m. The altitude difference was 300 m. In July, he required 1 hr 17 min for the ascent and 1 hr for the descent, together 2 hrs 17 min; in September and October, the time required for both ascent and descent was 2 hrs 15 min. In addition, we made hikes on October 3rd, from Coblence over Waldesch-Römerstrasse to the Fleckertshöhe (531 m above sea level) over hilly terrain at about 400 m elevation, requiring 5 hrs in all; for the descent to Bad Salzig/Rhine, we needed 30 min. The height difference was 460 m. We also hiked from the Colle d'Olen toward the Stolenberg, partly along the path leading to the Gnifetti Hut and partly over snow and rubble, with the path rising by 245 m. In this, we required 35, 36, and 45 min (with some climbing) for the ascent and 22, 27, and 27 min for the descent.

Between the weighings, we let about 2 hrs elapse. To obtain a criterion for the strain during these climbing tests, we counted our pulse after arriving at the goal and 5 min later. Immediately after arrival, we found values of 110 for Kr.II and values of 124 in the two other subjects; 5 min later, the value was 80 for Kr.II and 90 - 96 for the two other subjects. No difference between lowland and high elevation was observed. The blood pressure, measured with the Sahli apparatus, never showed changes. /418

CLIMBING EXPERIMENTS

	Cohnheim	Kreglinger I	Kreglinger II	
Heidelberg	780 g (150 g)	—	—	cloudy, 15—17°C
	880 »	—	—	rain, 16—18°C
	758 » (200 »)	—	—	cloudy, sultry, 13°C business suit.
	896 » (230 »)	—	—	sun, 17°C business suit.
	920 » (230 »)	—	—	sun, warm.
	1190 » (370 »)	—	—	sun, 21°C, very sultry
	850 » (130 »)	—	760 g (100 g)	sun.
	850 » (70 »)	—	810 » (100 »)	17°C, windy, sun.
	950 » (136 »)	—	770 » (112 »)	24°C, hot, sun.
	830 » (150 »)	—	660 » (95 »)	14°C, cloudy.
	800 » (68 »)	—	560 » (45 »)	17°C, cloudy, slight drizzle.
	950 g (121 »)	—	1000 »	26°C, sun.
Coblence	—	1600 g (180 g)	—	17°C, sun.
	—	1160 »	—	16°C, sun.
	—	720 » (280 »)	—	15°C, overcast.
	—	860 » (60 »)	—	15°C, sun.
	—	1500 »	—	12°C, partly foggy, partly sunny 5 1/2 hrs, no jacket.
Colle d'Olen	1000 g (250 g)	550 g (100 g)	1050 g (60 g)	sun, hot.
	800 » (300 »)	600 » (300 »)	550 » (50 »)	cooler, shady, some climbing.
	600 »	350 »	250 »	5—6°C, fog, some rain.

The above Table gives the weight loss in grams. The numerals in parentheses refer to the heavier clothing, i.e., not to the evaporated amount of perspiration, which was also determined in most cases*.

In addition, we made some other weighings before and after climbing, /419 using ourselves and some staff members of the Laboratory as subjects. These figures will be discussed below.

	Cohnheim Weight 84 kg g	Kestner Weight 76 kg g	Kreglinger I Weight 77 kg g	Kreglinger II Weight 87 kg g	Dr. A. Weight 67 kg g	Dr. S. Weight 64 kg g	Dr. G. Weight 76 kg g
3 hrs climbing in snowstorm	1600	—	1300	—	—	—	—
Path to the Gnifetti Hut, cold, windy 700 m rise	2250	—	1300	1600	—	—	—
Ascent to the Margh. Hut, 1560 m ascent, hot, little wind	4000	4100	3870	5800	2900[1])	1900[1])	—
7 hrs, part climbing, part ascent and descent	2400[1])	—	—	—	1600[1])	1350[1])	2150[1])

[1]) The numerals denoted by 1) represent minimal figures since there was considerable intake of liquid during the climb. For the other figures, the liquid or solid food as well as the excreted amount of urine were measured and taken into consideration.

These figures, as expected, indicate that the weight loss depended primarily on the temperature, insolation, and cloud cover; in addition, C. usually lost more weight than the already thin brothers Kreglinger. The difference was especially striking at lower temperatures and became somewhat less at elevated temperatures. Similar observations were made by Rubner et al. (Bibl.18, 14, 15).

* Of this unevaporated water, about two thirds were attributable in most cases to the flannel shirt which we wore together with our mountain-climbing outfit (Bibl.17).

The weight loss, during the night in Heidelberg, for Cohnheim was

in 10 hrs, 360 gm; in 9 hrs, 292 gm
211 gm; in 9 hrs, 350 gm
in 9 hrs, 300 gm; in 10 hrs, 243 gm
in 10 hrs, 243 gm; in $8\frac{1}{2}$ hrs, 295 gm

In Coblence, for Kreglinger I:

in $8\frac{1}{2}$ hrs, 320 gm
in $6\frac{1}{2}$ hrs, 150 gm
in 9 hrs, 300 gm

On the Colle d'Olen:

Cohnheim	Kestner	Kreglinger I	Kreglinger II
330	-	550	550
510	700	-	-
100	300	-	-

On the Margherita Hut:

	Cohnheim	Kestner	Kreglinger I	Kreglinger II
First night	350	500	200	0
Second night	225	470	600	100
Third night	150	300	500	750

* Here, only the negligible motion during dressing and undressing is included; urine excretion and liquid intake were measured and allowed for.

Finally, we also made two experiments in which we were exposed to intense sunshine for 1.5 - 3 hrs, lying on the Colle d'Olen until we started perspiring profusely without any muscular work. The weight loss was 500 gm in 1.5 hr; 550 and 850 gm in 3 hrs.

This weight loss naturally cannot be attributed exclusively to water evaporation; in addition to such evaporation, also fat and glycogen were burned and transpired; in addition, weight changes may be produced by oxygen consumption and other metabolic processes. According to data by Loewy and Durig (Bibl.19, 20), at most 100 ltr oxygen would be consumed for an ascent and descent of 345 m, to which the requirement at rest for 1.5 hr must be added. This would give 153 gm for glycogen combustion and 67 gm for fat combustion. For /421 9 - 10 hrs of rest, the figures given by Tigerstedt (Bibl.21) can be used for calculating a 160 gm decrease by glycogen and 85 gm by fat combustion. All other data, i.e., about 9/10 for the climbing tests and more than half for the tests at rest, are due to water evaporation. For this, no difference that was not directly due to temperature and insolation was observed in the climbing tests between 100 and 3000 m height above sea level. The situation is entirely different for the experiments at rest. As discussed in the Introduction, we believed it possible that the water vapor dissipation at rest, under exclusion of perspiration, might be much greater than in the lowland. In fact, we obtained several figures that are considerably higher than the rather constant figures obtained in Heidelberg and Coblence. In between, we also found surprisingly low differences in the evening and morning data. These differences most likely can be explained only by the fact that, after the strong muscular effort in ascent to the Margherita Hut and in other climbs, excessively intense processes accompanied by weight increase take place, such as - for example - the formation of oxygen-rich glycogen from other materials. This partly masks the weight loss through water evaporation and combustion. Even making allowance for the less restful sleep at the Margherita Hut, the perspiratio insensibilis at high altitudes obviously is much more extensive than in the lowland.

The greater water dissipation at high elevations would agree well with the observed hemoconcentration accompanying the increase in blood corpuscles per unit volume. However, it would be good to mention at this point that, in determining the hemoglobin content of our blood, we were unable to observe such a constant increase.

For determining the hemoglobin we used the Goners hemoglobinometer, modified by Haldane (Bibl.22). In this apparatus, the reference solution is a /422 carbon monoxide-hemoglobin solution. In all, 20 cc blood are taken, diluted with water to varnish color, bubbled through with manufactured gas, and further diluted until the color matches that of the standard solution. The reading is taken from a graduated dial on which 100% Hb corresponds to an oxygen combining power of 18.5%. Healthy human subjects have a hemoglobin content of 100. After some training, the apparatus will give highly accurate and reliable readings (Bibl.23). If the test is carefully done, the error will not exceed 2%. Since no manufactured gas was available in the Monte-Rosa Laboratories, we produced carbon monoxide by heating oxalic acid with sulfuric acid and conducting the generated gas through caustic soda solution. In addition to the Haldane hemoglobinometer, we also used that developed by Grützner, but found that the readings were much less accurate than those of the Haldane instrument, despite its extreme convenience; therefore, we will not give the obtained readings at this point.

The blood was taken with the Francke scarificator on the back of the finger nail phalanx. We were especially careful to take as large as possible a drop of blood so as to prevent admixture of lymph and tissue juice. Specifically, Zuntz and coworkers emphasized that the differing intensity of blood circulation in the skin could result in considerable errors in hemoglobin determinations and blood counts, meaning that less blood corpuscles would be counted at low temperatures than at high temperatures. We made an experiment on two of us, by taking blood in quick succession, first after immersing one hand in water of 6°C or after staying in the open at a temperature of 5°C and fog, until a distinct numbness of the fingers was felt; the second test was made after immersing the hand in water of 43 - 45°C, which produced distinct erythema of the hand: /423

	C.	Kr.II
Effect of cold	Hb 103	Hb 95
Effect of heat	Hb 106	Hb 99

Obviously, the differences are minor despite the fact that the conditions were rather extreme. Incidentally, we never took blood samples in the open.

Below, we give a compilation of the blood sampling, made in the morning before arising or at least at complete muscular rest.

	Cohnheim	Kestner	Kreglinger I	Kreglinger II	
Colle d'Olen					
Aug.1	110	-	101	97	
Aug.2	106 and 103	-	102	99 and 95	
Aug.3	99	-	90	-	
Aug.5	110	-	94	100	
Aug.6	116	98	98	-	Dr.A., 110
Margherita Hut					
Aug.7	110	-	93	98	
Aug.8	110	100	90	102	Dr.A., 110
Aug.9	102	102	96	-	L., 100
Colle d'Olen					
Aug.12	106	98	-	-	
	102	100	-	-	
Aug.13	108	108	-	-	Dr.S., 99
Aug.14	106	112	-	-	
Heidelberg					
April 24	98	-	-	-	
Sept.10	105	-	-	-	
Sept.19	-	-	-	-	

These figures show no increase in hemoglobin content. This result agrees with the data by Zuntz et al. but not with those obtained by many other authors, including Viault (Bibl.24), Miescher et al., Abderhalden, Giacosa (Bibl.25) and many others. In part, this difference is no doubt due to the fact that usually the blood count was made on human subjects and is presumably less accurate /424 than the Haldane hemoglobin determination. However, the most important experiments, specifically the numerous tests made by Abderhalden, were conducted with small animals; above, we substantiated our statement that these results are not applicable to human subjects. For a human subject at rest, we have demonstrated an increased water dissipation at high altitudes; since such water dissipation is not due to an increase of the sweat gland activity but rather to physical causes, it most likely is present also in small animals and even to a greater extent because of their rapid respiration and large body surface. Conversely, as also mentioned above, small animals of this type have no water regulation, a process that evolved in the human species because of the need for heat dissipation. In addition, data compiled by Verum (Bibl.26) should be recalled here; this author found a considerable increase in blood volume in penned rabbits as soon as they were exposed to sunlight. In earlier times, no attention had been paid to this point. Naturally, our negative results do not exclude the possibility that, on longer stay at high elevations, the number of blood corpuscles might increase under the stimulating effect of oxygen depletion. On the Colle d'Olen, i.e., at an elevation of 3000 m, we discovered no specific altitude effect. On the Margherita Hut (4560 m), we detected no symptoms of mountain sickness but we found that, a fact described by all earlier observers, even the slightest muscular work - such as a few minutes of dumbbell lifting or snow shoveling - produced dyspnea; in addition, any hemoglobin determination showed a distinctly dark venous color of the blood. Finally, independent of the altitude, the blood concentration in human beings may fluctuate within a short period of time.

In accordance with our above-discussed experimental schedule, we made hemoglobin determinations not only at rest but also immediately after the climb- /425 ing tests; we found that, under the effect of this muscular exertion, the concentration of hemoglobin decreased.

		Cohnheim		Kestner		Kreglinger I		Kreglinger II	
		Rest	Work	Rest	Work	Rest	Work	Rest	Work
Colle d'Olen	1st Aug	110	101	—	—	101	95	[illegible]	101
		—	99	—	—	—	93	—	91
	6 »	116	102	—	—	—	—	—	—
Colle d'Olen (Margherita)	7 »	—	—	—	—	98	99	—	—
Margherita Hut	8 »	110	97	100	93	90	[illegible]	102	98
	9 »	102	99	[illegible]	99	—	—	—	—
	10. »	—	99	—	—	90	90	—	[illegible]
	11 »	—	99	—	—	—	—	—	—
	12 »	106	—	104	—	—	—	—	—
		108	—	100	—	—	—	—	—
	13 »	108	—	108	—	—	—	—	—
	14 »	106	100	112	102	—	—	—	—
Heidelberg	10th Sept	105	95	—	—	—	—	—	—
	25 »	106	104	—	—	—	—	—	—
Bonn		—	—	—	—	—	—	82 [1])	76 [1])
		—	—	—	—	—	—	84 [1])	84 [1])
		—	—	—	—	—	—	86 [1])	84 [1])

[1]) Determinations were made with Sahli's apparatus (hematin); for the climb, 20 min gymnastics were substituted.

Consequently, whereas most authors had observed a constancy or a minor increase in hemoglobin concentration during muscular exertion (Bibl.27, including earlier literature by Grawitz, Winternitz, and others), these experiments - with a single exception - resulted in hydremia under the influence of climbing. It is quite certain that this result was not simulated by experimental errors, /426 since the blood circulation became more intense on heating and perspiration, which would mean that the figures should actually have been higher. In experiments in the lowland, such hydremia occurred occasionally or, at least once, was not observed. The investigation will have to be repeated for lowland conditions. We are unable to say definitely whether any type of muscular work will have this effect. For example, a simple walk of 20 min on the Colle d'Olen did not lead to a decrease in hemoglobin:

	C.	S.
Before	108	99
After	108	98

Perspiration alone, without muscular exertion, did not lead to hydremia, as shown by a few experiments made on the Colle d'Olen. We (Cohnheim and Kestner) exposed ourselves to the sun until profuse perspiration took place (weight loss, 500 - 850 gm) and determined the hemoglobin before and after exposure.

	C.	C.	K.	C.	K.	K.
Before	106	102	100	-	-	-
After	108	103	100	108	108	104

Accordingly, it seems that hydremia is a consequence of muscular work. From the working muscles water is transferred to the blood. One must recall that, according to observations by Magnus and Engels, the musculature constitutes a water depot of the body. It might well be that the active muscles expel the accumulated excess water. However, it seems more probable that, simultaneously with the muscular activity, leading to a greater heat production and thus to an increased stress on the sweat glands, water is given off into the blood to compensate for the resultant water loss, thus leading to an overcompensation. In this particular field, overcompensations of other types are well known, namely, the excessive rise in metabolic rate after a cold bath (Bibl.28, 29) or the increased depth of pulmonary respiration during muscular work (Bibl.30, 27). /427

It is known that sodium chloride is excreted from the human organism through the urine but also through the perspiration. The data on the percentage of salt in the perspiration fluctuate (Bibl.31, 17, 32, 33); absolute amounts of sodium chloride were determined by Cramer and Schwenkenbecher (Bibl.17, 32, 33) but, in profuse perspiration after strenuous exertion, the sweat production no doubt is much greater than given by Cramer. We used the climb from the Colle d'Olen to the Margherita Hut, which was connected with profuse perspiration, for studying the chlorine metabolism under these conditions and also the possible consequences of a strong chlorine loss in the perspiration itself.

Up to the ascent, we stayed on the regular diet offered by the Institute Mosso, with the daily chlorine excretion, according to occasional tests, fluctuating about 10 gm. Starting from the morning of the ascent, we kept a diet of which the salt content was more or less known. The salt added to the food was weighed for each individual and chlorine analyses were made of such food items as ham, bacon, cheese, and meat extract; the samples were freed of fat in a Soxhlet, and the residue was boiled with water until removal of the entire chlorine. The sodium chloride in the extract was determined according to Volhard's method. Of the other foodstuffs, consumed on the Margherita Hut, only traces of chlorine were contained in the meat, unsalted butter, eggs, chocolate, sugar, and fruit; somewhat larger and not fully determined amounts are present only in bread. The water, which was melted snow, was completely free of chlorine.

The weight losses during the ascent have been given on p.7. These losses were 3870, 4000, 4100, and 5800 gm. This constitutes the pure so-called /428 "perspiratio insensibilis", i.e., the weight difference reduced by the excreted urine and increased by the ingestion of solid and liquid food during the hike. The ascent, with some rest periods, took 7 hrs, mostly in hot sunshine and at negligible wind. The altitude difference was about 1600 m. All four carried a rather large pack of supplies. The load, above our body weight without clothing, was 19 kg for Kr. I, 18 kg for Kr. II, 14 kg for C., and 12 kg for K. In the last hour, all participants felt extreme fatigue, which frequently forced them to stop and rest. The blood pressure (determined by Sahli's test) dropped from 140 to 90 in Kr. II, which definitely was a symptom of overfatigue. In the two other subjects, listed in the Table on p.11, who made the ascent with a heavy pack in 5 hrs on the next day under the same weather conditions, the blood pressure dropped to 90 and 100 mm Hg*.

We collected the urine of the day of ascent up to shortly before the evening meal and the urine of the next two days always from evening to evening, of which we determined the chlorine content according to Volhard's method. On these days, we avoided excessive muscular exertion; since it was quite cold on the mountaintop, no chlorine was excreted with the perspiration so that the urine test showed a complete balance.

The results are given in the accompanying Table.

	Cohnheim Wt. loss 4000 g			Kestner Wt. loss 4100 g			Kreglinger I Wt. loss 3870 g			Kreglinger II Wt. loss 5800 g		
	Total Urine cc	ClNa-In-take g	ClNa-Ex-cret. g	Total Urine cc	ClNa-In-take g	ClNa-Ex-cret. g	Total Urine cc	ClNa-In-take g	ClNa-Ex-cret. g	Total Urine cc	ClNa-In-take g	ClNa-Ex-cret. g
Afternoon of the day of ascent	300	trace	3.46	620	trace	5.2	660	trace	5.6	50	trace	0.49
Second day	780	17	6.9	670	17	3.48	720	20	5.3	460	17	3.68
Third day	1600	17.5	18.2	1410	14.5	8.3	1000	18.5	13.9	1000	15	14.4

* For footnote see following page.

It was found that, on the day of strong chlorine secretion, the chlorine excretion was relatively high in at least three of us but that, on the next day, at abundant salt intake, the body energetically retained chlorine. Chlorine /429 retention is well known from pathological cases, such as renal insufficiency, edematous conditions, or inflammatory effusion**, or else in infants during replenishing of fluids lost in recovery from digestive upset. In healthy subjects, we have no knowledge of such strong chlorine retention. This retention of 10 - 14 gm per day shows that the sodium chloride reserves of the human body can be depleted by profuse perspiration and then will have to be replenished. If the sodium chloride is not used up by the sweat glands, the chlorine excretion - after stoppage of the supply - by no means decreases rapidly. In Heidelberg, one of us (C.) lived on a low-salt diet for three days, on which he did not perspire; this diet contained no more than 1 gm sodium chloride per day. The following excretions were observed:

First day, 2140 cc urine with 9.84 gm ClNa

Second day, 1168 cc urine with 3.3 gm ClNa

Third day, 1096 cc urine with 2.47 gm ClNa.

Consequently, despite a decreased salt intake on these days, the excretion in the urine continued, in complete contradiction to the strong retention after losses in the perspiration.

The extensive salt losses through perspiration may be of significance in

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* That no altitude effect as such was involved here was proved by the case of two porters who climbed from the Gnifetti to the Margherita Hut on the next day, carrying loads of 36 and 42 kg; on arrival, these showed a pulse rate of 78 and 80 at a blood pressure of 125 and 130 mm Hg, without increase in cardial dulness (see Mosso, "Man in the High Alps").

** For the entire problem complex of sodium chloride metabolism, see the Proceedings of the Congress on Internal Medicine, 1909.

two directions. First, it must be assumed that the replenishing of the lost water proceeds more rapidly and more completely if salt is supplied simultaneously. Presumably, the well-known experience that water drinking does not /430
always still strong thirst can be interpreted in this direction; no experiments on this point have been made by us. Secondly, the sodium chloride is used by the body as the starting material for producing the hydrochloric acid of the gastric juice. It is known that sodium chloride losses in dogs greatly impair their hydrochloric acid secretion. On the morning after ascent to the Margherita Hut, i.e., before the day of intense chlorine retention, we took a test meal (400 gm tea and 40 gm bread) and expressed the stomach content 45 - 55 min later, titrating the free hydrochloric acid with Congo paper and the total acidity with phenolphthalein. We found the following results:

	Cohnheim	Kestner	Kreglinger I	Kreglinger II
Free HCl	47	too little content for titration	10	21
Total acidity	65	hardly diluted, HCl +	26	32

This means that three of us showed a distinct reduction in gastric juice secretion; this was absent in only one of us (C.) in whom, presumably because of the negligible perspiration, the chlorine retention was least pronounced. Since we all felt completely fit and unfatigued on the morning and had no gastric complaints, no other reason can be given for the observed subacidity; consequently, we feel justified to assume that the chlorine loss of the preceding day was the true cause.

We used the urine samples, collected on the Margherita Hut, for further tests. Of the amount, we mixed 10 cc with three drops of NO_3H and determined the amount of 1% $KMnO_4$ solution which was decolorized by this. In addition, the specific gravity and acidity (phenolphthalein) were determined.

	Cohnheim			Kestner			Kreglinger I			Kreglinger II		
	Sp. Grav.	$KMnO_4$ in cc	Acidity	Sp. Grav.	$KMnO_4$ in cc	Acidity	Sp. Grav.	$KMnO_4$ in cc	Acidity	Sp. Grav.	$KMnO_4$ in cc	Acidity
Day of ascent	1040	4.7	7.5	1030	3.9	6.0	1020	5.6	5.2	[illegible]	3.8	6.6
Second day	1030	6.3	6.0	1020	5.5	5.6	1030	4.2	5.4	1040	4.7	7.0
Third day	1020	0.7	3.6	1018	0.8	2.7	1025	0.7	—	1025	0.6	5.9

Thus, the acidity does not increase more than would correspond to the higher specific gravity. Conversely, the urine of the working day and of the immediately following resting day contained 6 - 8 times more substances that decolorized permanganate in acid solution.

The main results can be summarized as follows:

1) No definite increase in hemoglobin concentration in human subjects was observed at 3000 and 4560 m elevation.

2) Increased muscular work led to transitory hydremia.

3) Profuse perspiration resulted in chlorine depletion of the body which, on subsequent days, was compensated by increased chlorine retention.

4) Chlorine depletion may lead to interference with gastric hydrochloric acid secretion.

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